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PROXY NETWORK LAYER PROTOCOL SUPPORT IN A WIRELESS COMMUNICATION NETWORK

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] This invention relates generally to the field of wireless communications. More particularly, this invention relates to a novel method and system for supporting a network layer protocol in a network element of a wireless communication network.

Description of Related Art

[0002] Recent innovations in wireless communication and computer-related technologies, as well as the unprecedented growth of Internet subscribers, have paved the way for mobile computing. In fact, the popularity of mobile computing has placed greater demands on the current Internet infrastructure to provide mobile users with more support. A crucial part of meeting these demands and providing users with the necessary support is the use of Code Division Multiple Access (CDMA) technology in wireless communications systems.

[0003] CDMA is a digital radio-frequency (RF) channelization technique first defined in the Telecommunications Industry Association/Electronics Industries Association Interim Standard-95 (TIA/EIA IS-95), entitled "MOBILE STATION-BASE STATION COMPATIBILITY STANDARD FOR DUAL-MODE WIDEBAND SPREAD SPECTRUM CELLULAR SYSTEM," published in July 1993 and herein incorporated by reference. Recently promulgated CDMA standards include TIA/EIA/IS-835-A, entitled "CDMA2000 WIRELESS IP NETWORK STANDARD," published in May 2001 and herein incorporated by reference; TIA/EIA/IS-856, entitled

"CDMA2000, HIGH RATE PACKET DATA AIR INTERFACE SPECIFICATION," published in November 2000 and herein incorporated by reference; TIA/EIA/IS-2000.1-A, entitled "INTRODUCTION TO CDMA2000 STANDARD FOR SPREAD SPECTRUM SYSTEMS," published in March 2000 and herein incorporated by reference; and TIA/EIA/IS-707-A, entitled "DATA SERVICE OPTIONS FOR WIDEBAND SPREAD SPECTRUM SYSTEMS," published in April 1999 and herein incorporated by reference. TIA/EIA/IS-856 is also known as 1xEV. Wireless communications systems employing CDMA technology assign a unique code to communication signals and spread these communication signals across a common (wideband) spread spectrum bandwidth.

[0004] Other support is made possible by applying various well-known protocols to control, manage, or otherwise facilitate different aspects of wireless communications. For example, the lifeblood of the Internet infrastructure, the Internet Protocol (IP), has been incorporated in many wireless communication services to accommodate packet-oriented services. The IP protocol is a network layer protocol that encapsulates data into IP packets for transmission. In particular, the IP protocol specifies the addressing and routing of packets (datagrams) between host computers.

[0005] Version 4 of the IP protocol ("IPv4") is defined in Request For Comments 791 (RFC 791) entitled "INTERNET PROTOCOL DARPA INTERNET PROGRAM PROTOCOL SPECIFICATION," published September 1981, and herein incorporated by reference. Although the most widely used version of the IP protocol, IPv4 has a number of limitations, including its provision of a relatively limited number of network addresses, which uniquely define all devices accessing the Internet. IP Version 6 ("IPv6"), the "next generation" IP protocol, has been designed to replace IPv4 and is defined in RFC 2460, "INTERNET PROTOCOL, VERSION 6 (IPV6)

SPECIFICATION," published December 1998, and herein incorporated by reference. IPv6 mitigates some of the limitations of IPv4, including the limited number of available IPv4 addresses. Additionally, IPv6 improves upon IPv4 in numerous respects, such as routing and network autoconfiguration schemes. Herein, the term "IP protocol" is used where a concept is applicable to both IPv4 and IPv6. For version-specific concepts, the terms IPv4 and IPv6 are used.

[0006] IPv6 is expected to eventually replace IPv4. However, the two protocols will likely coexist for some time as the world transitions to IPv6. Most applications currently in use, whether for personal computers (PCs) or mobile devices, are built upon IPv4 exclusively, and it is likely that many of these devices will not or cannot be modified to support IPv6. Application support for IPv6 will likely emerge gradually.

[0007] Differences exist between the handling and operations of IPv4 and IPv6 protocols. Given the near-term coexistence of IPv4 and IPv6, tunneling approaches have been proposed to support the compatibility of IPv4 and IPv6. In accordance with a tunneling approach, two networks supporting the same version of a protocol can communicate even if they are separated by a network that does not support that version of the protocol. This is achieved by encapsulating the datagrams of the unsupported protocol inside datagrams of the protocol supported by the intermediary network.

[0008] In the case of a wireless network, the packets conforming to a protocol unsupported by a packet data serving node (PDSN) are encapsulated within packets conforming to a protocol supported thereby. The encapsulated packets are sent by the mobile device to the PDSN, which may then forward all or a portion of the packets to a router that does support the protocol unsupported by the PDSN. In order to support tunneling, however, mobile devices may require various modifications to their existing configurations. Such modifications increase the complexity and cost of mobile devices.

Moreover, tunneling operations may result in the inefficient use of processing resources, as well as a decrease in data throughput.

[0009] Another well-known protocol incorporated in wireless communications systems is the Point-to-Point Protocol (PPP) protocol, which provides, inter alia, Internet access. The PPP protocol is described in detail in Request for Comments 1661 (RFC 1661), entitled "THE POINT-TO-POINT PROTOCOL (PPP)," published July 1994 and herein incorporated by reference.

[0010] Essentially, the PPP protocol specifies a method for transporting multi-protocol datagrams over point-to-point links and contains three main components: a method of encapsulating multi-protocol datagrams; a Link Control Protocol (LCP) for establishing, configuring, and testing a data link connection; and a family of Network Control Protocols (NCPs) for establishing and configuring different network layer protocols.

[0011] The PPP protocol supports multiplexing and demultiplexing of datagrams conforming to multiple protocols. Specifically, PPP encapsulation is employed to distinguish among multi-protocol datagrams. Each encapsulated frame includes, in addition to an Information field and a Padding field, a Protocol field whose value (protocol ID) identifies the datagram encapsulated in the Information field of the packet. The structure of this field may be 8 or 16 bits in length. Frames received which do not comply with associated addressing rules must be treated as having an unrecognized protocol.

SUMMARY OF THE INVENTION

[0012] Systems and methods consistent with the principles of the present invention, as embodied and broadly described herein, provide for a novel method and

unframing any received PPP packets and reframing them before forwarding them to their final destination as well as providing mobility management and network address management. In the MT0 model, a protocol stack of MT device 104 is used to support applications running on MT device 104 itself.

[0032] Consistent with the Relay Model, system 200 includes TE device 102, MT device 104, PDSN 108, and a router 290. The TE protocol stack of TE device 102 is illustrated as being logically connected to the PDSN 108 protocol stack via an R_m interface between TE device 102 and MT device 104, and a U_m/A interface between MT device 104 and PDSN 108. The PDSN 108 protocol stack is illustrated as being logically connected to the router 290 protocol stack over a link 280.

[0033] TE device 102 includes network layer protocols 206. In the embodiment shown, TE device 102 supports both the IPv4 and IPv6 network layer protocols. TE device 102 also includes link layer protocols 208. In particular, TE device 102 supports PPP protocol 208.

[0034] TE device 102 includes relay layer protocols 210 to allow transmission of packets, encoded by PPP layer 208, across the R_m interface to MT device 104 using an applicable protocol. An exemplary relay layer protocol is the TIA/EIA 232-F protocol. Associated RS-232 interfaces 210, 212 in TE device 102 and MT device 104, respectively, are shown in FIG. 2. The TIA/EIA-232-F standard is defined in "INTERFACE BETWEEN DATA TERMINAL EQUIPMENT AND DATA CIRCUIT-TERMINATING EQUIPMENT EMPLOYING SERIAL BINARY DATA INTERCHANGE," published in October 1997 and herein incorporated by reference. It is to be understood that other standards or protocols known to artisans of ordinary skill in the art may be used to define the transmission across the R_m interface. For example, other applicable R_m interface standards may include th "UNIVERSAL SERIAL BUS

(USB) SPECIFICATION, Revision 1.1," published in September 1998, and the "BLUETOOTH SPECIFICATION VERSION 1.0A CORE, published in July 1999, both incorporated by reference.

[0035] MT device 104 includes an air link 214, which serves to connect MT device 104 to an A interface link 220 in PDSN 108 over the U_m/A interface. RAN 130 is not explicitly shown in system 200. RAN 130 bridges the air link and the A interface to allow data to flow between MT device 104 and PDSN 108.

[0036] Air link 214 may employ the Radio Link Protocol (RLP) and the IS-856, IS-2000, or IS-95 protocols, for example, to transmit packet-encapsulated PPP frames to PDSN 108 over the U_m/A interface. A version of the RLP protocol is defined in the IS-707.2 standard, entitled "DATA SERVICE OPTIONS FOR WIDEBAND SPREAD SPECTRUM SYSTEMS: RADIO LINK PROTOCOL," published in February 1998 and herein incorporated by reference. A version of the RLP protocol for IS-856 (1xEV) is defined in TIA/EIA-136-310-A-1, entitled "TDMA THIRD GENERATION WIRELESS—RADIO LINK PROTOCOL—1, ADDENDUM 1," published in June 2001 and herein incorporated by reference. The IS-856, IS-2000, and IS-95 protocols are defined in the standards identified above. Other standards may be employed by artisans of ordinary skill.

[0037] PDSN 108 includes network layer protocols 230. In the embodiment shown, PDSN 108 natively supports the IPv6 network layer protocol, IPv6CP, and header compression/decompression algorithms. Additionally, PDSN 108 supports Van Jacobson IPv4 header compression through the IPCP protocol stack (described below). PDSN 108 also includes data link layer protocols 232. In particular, PDSN 108 supports PPP protocol 232. PDSN also includes an A interface link 220, a physical layer (PL) 236, and a link layer 234.

[0038] A interface link 220 receives packets from MT device 104 over the U_m/A interface provided by RAN 130 and transfers the received packets to PPP layer 232. PPP layer 232 then unframes the received packets and transfers them to the network layer protocol 230, which in turn either passes them to upper layer protocols (not shown) or forwards them to their final destination.

[0039] Router 290 includes a network layer protocol 260, a link layer 265, and a physical layer 270. In the embodiment shown in FIG. 2, router 290 supports the IPv4 network layer protocol. A physical layer (PL) 236 of PDSN 108 is operatively coupled to a physical layer 270 of router 290. As such, router 290 may provide PDSN 108 with connectivity to various networks, such as the Internet or intranets. In some embodiments, router 290 may be operated by an Internet service provider (ISP).

[0040] The configuring, enabling, and disabling of the network layer protocol modules 206, 230 on both ends of the PPP link is provided by control protocols. Specifically, for IPv4, the Internet Protocol Control Protocol (IPCP) is employed. IPCP is a part of a family of network control protocols included in the PPP protocol and described in Request for Comments (RFC) 1332, "THE PPP INTERNET PROTOCOL CONTROL PROTOCOL (IPCP)," published in May 1992 and herein incorporated by reference.

[0041] IPCP utilizes configuration request messages to negotiate various configuration options. One such option is the IP Header Compression Protocol Option. When enabled, this option generally employs the Van Jacobson (VJ) compression methodology for compressing the TCP/IP headers in a PPP packet. The Van Jacobson compression methodology improves the efficiency of a protocol by reducing the overhead in the packet headers and is described in RFC 1144 entitled, "COMPRESSING TCP/IP HEADERS FOR LOW-SPEED SERIAL LINKS,"

published in February 1990 and herein incorporated by reference. The Van Jacobson compression methodology is a compression algorithm that relies on knowledge of the fields in the TCP/IP headers to determine how they are likely to change from packet to packet. IPv4 packets may be of type straight IPv4, VJ compressed, and VJ uncompressed.

[0042] The IPv6 analogue of IPCP is the IPv6 Control Protocol (IPv6CP). IPv6CP is described in Request for Comments (RFC) 2472, "IP VERSION 6 OVER PPP," published in December 1998 and herein incorporated by reference. An IPv6-Compression-Protocol Configuration Option provides a way to negotiate the use of a specific IPv6 packet compression protocol. The IPv6-Compression-Protocol Configuration Option is used to indicate the ability to receive compressed packets. As stated above, PDSN 108 includes support for IPv6CP.

[0043] FIG. 3 is a high-level block diagram of a system 300 for supporting a network layer protocol according to an embodiment of the present invention. Protocol stacks of system 300 may be the same as those of system 200 described above. System 300 includes a PPP multiplexer 360, PPP demultiplexer 310, IPv6 decompressor 320, IPv4 (Van Jacobson) decompressor 330, IPv6 protocol stack 340, IPv6 compressor 367, IPv4 (Van Jacobson) compressor 370, and IPv4 protocol stack 350. Modules to the left of the dashed line reside in a PDSN 308 and modules to the right thereof reside in a router 390.

[0044] Thus, in the embodiment shown in FIG. 3, PDSN 308 includes native support for the IPv6 protocol, IPv6CP support, and IPCP support. Accordingly, PDSN 308 may unframe and apply header compression and decompression algorithms to IPv4 packets. Router 390 natively supports the IPv4 protocol and includes IPCP support.